1977

The Relationship of Temporal and Spatial Parameters in Backward Masking

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THE RELATIONSHIP OF TEMPORAL AND SPATIAL PARAMETERS IN BACKWARD MASKING

by

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A Thesis Submitted to the Faculty of the Graduate School

of Loyola University of Chicago in Partial Fulfillment

of the Requirements for the Degree of

Master of Arts

May

1977

ACKNOWLEDGMENTS

I would like to thank Dr. Richard Bowen, Dr. Mark Mayzner, and Dr. Richard Fay for their helpful criticisms throughout this project. Special thanks go to Dr. Mayzner for the use of his equipment and to Dr. Bowen for the time and interest he invested in this thesis.

Also, I would like to especially thank my husband, James, for his help in acting as a subject, and for his encouragement and support.

VITA

The author, Darlene Cacciato Habinek, is the daughter of Harry L. Cacciato and Roberta (Ringholz) Cacciato. She was born January 24, 1950, in Chicago, Illinois.

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She is the third author of a paper, "Metacontrast Masking Depends on Luminance Transients" (Vision Research, in press), co-authored with Richard W. Bowen and Joel Pokorny.

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INTRODUCTION

The term visual masking refers to the fact that the appearance of a brief test stimulus can be affected by a masking stimulus that is placed in close spatial or temporal contiguity. The effects of the mask upon the test can be operationally defined, for example, as an increase in the threshold of the test or a decrease in per cent correct in recognition or detection tasks in which the test is the target. Kahneman, in his 1968 review of the masking literature, distinguishes among several types of visual masking, and it will be helpful to follow his example here. Backward masking refers to the case in which the test stimulus precedes the masking stimulus in time, and forward masking occurs when the masking stimulus is presented before the test stimulus. In both backward and forward masking the test and masking stimuli overlap spatially. In other cases in which the test and masking stimuli do not so overlap, the terms metacontrast and paracontrast are used to describe the same temporal conditions as backward and forward masking, respectively. This proposal deals with a backward masking paradigm, and the following review will be mainly restricted to that area.

In these experiments I will attempt to explore the effects on masking of varying the temporal and spatial relationships between the test and masking stimuli. Specifically, duration thresholds, (i.e., the duration of the test stimulus which can be just detected by the subject in a backward masking paradigm), will be obtained for three test stimuli which exhibit varying degrees of spatial overlap with a masking stimulus. The interstimulus interval (ISI) between the offset of the test stimulus and the onset of the masking stimulus will also be systematically manipulated across all three stimulus conditions. Few studies in the backward masking literature have made the relationship between temporal and spatial factors their main concern, although many have treated them separately. Several investigators (e.g., Donchin, 1967; Haber & Nathanson, 1969) found the time from the onset of the test stimulus to the onset of the masking stimulus to be the temporal factor that determines the amount of masking that will take place in a backward masking paradigm. Others (e.g., Kinsbourne & Warrington, 1962; Turvey, 1973) have found the time from the offset of the test stimulus to the onset of the masking stimulus to be the critical temporal determinant of masking. Since it has been shown by several researchers (e.g., Battersby & Wagman, 1962; Kolers, 1962) that as the degree of spatial overlap between the masking stimulus and the test stimulus increases that the amount of masking also increases, this author believes that some of the controversy about the true temporal determinant of masking may be settled if the spatial characteristics of the test and masking stimuli are taken into account. A thorough psychophysical investigation of these factors is now therefore in order.

It is necessary, however, to point out that many of the experiments included in the following review have employed widely differing paradigms. Digits (e.g., Mayzner & Greenberg, 1971); letters (e.g., Schiller, 1965 and 1966; Uttal, 1971); discs (e.g., Frumkes & Sturr, 1968; Kolers, 1962); bars (Sekuler, 1965); and trigrams (Turvey, 1973) have been used as test stimuli. The masking stimulus has taken many forms, including homogeneous fields (e.g., Donchin, 1967; Schiller, 1966); random noise (randomly arranged dots or lines; e.g., Kinsbourne & Warrington, 1962; Scharf & Lefton, 1970; Uttal, 1971); and specific patterns (e.g., Haber & Nathanson, 1969; Schiller, 1966). These stimuli have been presented as black figures on white backgrounds (e.g., Schiller, 1965; Sekuler, 1965) and as flashes of light (e.g., Frumkes & Sturr, 1968; Schiller, 1966; Stecher, 1971). Subjects have been required to identify stimuli (e.g., Haber & Nathanson, 1969; Mayzner & Greenberg, 1971) or merely to detect their presence (e.g., Sekuler, 1965; Stecher, 1971). The problem here is that it is often difficult or even impossible to make comparisons among the data from studies that differ in one or more of the above-mentioned respects. Turvey (1973), for example, obtained different masking effects depending upon whether he used a black pattern or black random noise as a masking stimulus. When Kolers (1962) compared masking of black-on-white and light-flashed stimuli, he found that the ". . . effects of stimulation with black forms in masking experiments are not mirror images of those obtained with flashes of light. . ." For this reason, then, the reader must keep in mind that the studies in the review to follow are not all strictly comparable and that discrepancies across findings may be due to minor differences in paradigm.

REVIEW OF RELEVANT BACKWARD MASKING LITERATURE

Temporal Studies

One of the most consistent findings in the area of backward masking is that as the ISI between the test and masking stimuli is increased, the degree of masking decreases. This has been shown for the recognition of light-flashed letters serving as both test and masking stimuli (Schiller, 1966); black letters masked by black patterns (Schiller, 1965); light-flashed letters masked by random dots (Uttal, 1971); and sequences of black letters masked by random patterns (Scharf & Lefton, 1970). Similarly, Kolers (1962) found that the duration thresholds of light flashes serving as test stimuli always increased monotonically as the ISIs between them and the masking flashes decreased, and the intensity threshold of light-flashed test stimuli determined by Battersby and Wagman (1959) also rose with decreasing ISI. Finally, Sekuler's (1965) measures of the duration thresholds of a single black bar when masked by spatial frequency gratings at varying ISIs exhibited the same relationship between ISI and test threshold mentioned above.

Despite the fact that all of these studies demonstrated that increased ISI led to decreasing masking effects, there has been some question as to whether ISI was really the critical temporal determinant of masking. That is, do changes in ISI affect the degree of masking that takes place, or is ISI merely confounded with some other variable that really determines the extent of masking? Kahneman (1967), for example, showed that the time elapsed between the onsets of the test and masking stimuli, or stimulus onset asynchrony (SOA), was of crucial importance in determining the extent of metacontrast masking. Donchin (1967) found the same result within a backward masking paradigm. He presented subjects with a semicircular test stimulus, which could be in one of eight positions, followed by a 10 msec masking disc. Both stimuli were light flashes, and the subjects' task was to identify which position the test stimulus was in. The luminance and duration of the test stimulus were varied over trials. Donchin employed the "critical masking interval"--that is, the ISI at which the probability of a correct response was equal to 0.5--as his dependent measure of masking. He found that when he plotted his data as a function of simultaneous onset asynchrony (SOA), the effects of test stimulus duration were much less pronounced than when the data were plotted as a function of ISI. This suggested to the author that when ISI was used as the critical masking variable that the effects of test stimulus duration were confounded with those of SOA.

Kinsbourne and Warrington (1962), however, demonstrated that ISI had a substantial effect upon the extent of backward masking. They utilized black-on-white letters as test stimuli and a random pattern ("visual noise") as a masking stimulus. The durations of the mask and the test were varied from 2.5-1600 msec and from 2.5-8 msec, respectively. The dependent variable was the ISI at which the subject could correctly identify the test stimulus. These authors found that at the minimum ISI at which the mask was no longer effective, that ISI X test stimulus duration = a constant. If SOA were the critical variable, the relationship would have been found to be ISI + test stimulus duration = a constant. Turvey (1973) replicated Kinsbourne and Warrington's findings with symmetric letters as test stimuli. He concluded that "it is quite evident that the formulation target duration X critical interstimulus interval = a constant argues strongly against onset-onset time and for target duration as the relevant parameter in masking by noise." Thus, the results of Kinsbourne and Warrington and of Turvey indicate that the way in which the interval of time from the onset of the test stimulus to the onset of the masking stimulus is divided between test stimulus duration and ISI is important in determining the amount of masking that will occur.

To further complicate the issue Turvey obtained conflicting results in a later experiment (Experiment XII), when he compared the results of using a black random noise mask and a black patterned mask. He found that when black trigram test stimuli were followed by a random noise mask that the resulting data followed the Kinsbourne and Warrington formula--target duration X critical ISI = a constant--and that the same was true of trigram test stimuli at very brief durations (i.e., 2-3 msec) followed by a patterned mask. At longer durations (i.e., 4-16 msec) of the test stimulus, on the other hand, masking by a patterned stimulus yielded data that obeyed the following formula--target duration + critical ISI = a constant. In other words depending upon the type of mask used and the duration of the test stimulus, the same author found that either SOA or ISI could be the critical temporal determinant of the extent of masking (see Figure 1).

Additional studies dealing with this problem have failed to agree upon which temporal parameter is the most important in backward

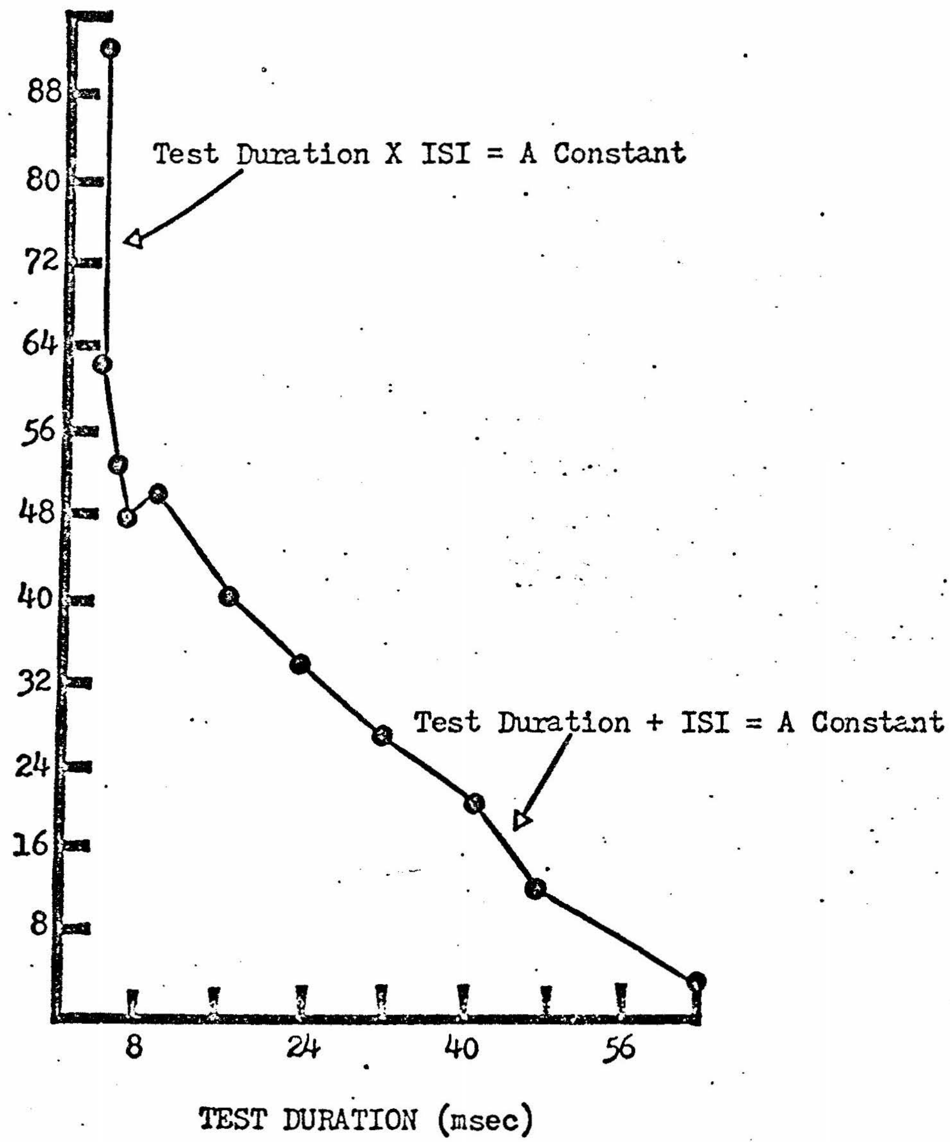


Figure 1. Relationship between test duration and the mean critical interstimulus interval for monoptic masking by a pattern mask. Modified from Figure 12 in Turvey, M. T., 1973.

masking. Haber and Nathanson (1969) utilized a rather unusual paradigm in which the individual letters of words were sequentially presented to the same spatial location so that each succeeding letter served as a backward mask for the letter which preceded it. Words of 4-8 letters were employed as light-flashed stimuli, with durations and ISIs varying from 10-150 msec. Subjects were instructed to begin identifying the individual letters of each word after the last letter of the word had appeared. They were told to make no attempt to name the word itself. These authors found that it made little difference in the subjects' performance how the time from the onset of one letter to the onset of the next (or total processing time) was divided between test duration and ISI, and they concluded that SOA predicted letter recognition within their paradigm better than either test duration or ISI.

An obvious confound in the Haber and Nathanson study is the fact that they used sequentially presented <u>words</u> as stimuli. Even though subjects were instructed not to attempt to name the words presented on each trial, the possibility exists that subjects were able to "fill in the gaps" of individual letters they did not perceive by guessing at the entire word. This possibility is heightened even further because the authors used the 250 most frequently used words of each word length from the Thorndike-Lorge word frequency count. A study by Mayzner and Greenberg (1971, Study 2) utilized a similar paradigm with randomly constructed input strings of 2, 3, and 4 digits. These stimuli were light flashes and were successively presented to the same spatial location. Total processing time (or SOA) of 5-75 msec was partitioned into various different combinations of stimulus duration ("on time") and ISI ("off time"). Again, the subjects' task was to identify the digits in each string after the last digit in a string had been displayed. Mayzner and Greenberg found that the way in which the onset-onset interval for each digit was divided between digit duration and ISI did indeed have an effect upon recognition performance. The authors concluded that although Haber and Nathanson found that SOA or total processing time was the only critical temporal variable in masking, that their own results indicated that the way in which the total processing time was divided between on and off times for each digit had effects which were "large, significant, and highly complex."

One thing which is clear at this point is that all of the above studies differed in many respects. The type of test stimuli and the nature of the mask varied across studies, as did the mode of presentation (black on white versus light-flashed) of the displays. Furthermore, the studies by Haber and Nathanson and by Mayzner and Greenberg are not comparable to the other experiments reviewed in that they used paradigms in which both forward and backward masking could occur (except in the case of Mayzner and Greenberg's 2-digit strings). Any of these differences in technique could possibly account for the differences in findings which have been obtained in these studies. It is therefore difficult to conclude exactly what temporal variable is the principle determinant of the extent of backward masking, and it is for this reason that this proposal will explore the temporal parameters involved in masking as one of its main objectives.

Spatial Factors

Another aspect of the backward masking phenomenon which has attracted some attention is the effect of spatial parameters upon masking. Liss (1968) concluded from the results he obtained in an experiment in which arrays of letters were masked by a pattern that ". . . it appears that backward masking stops stimulus processing whenever the spatial analysis of both the stimulus and the mask requires the use of the same central mechanism" This may be interpreted as meaning that the greater the similarity or amount of spatial overlap between the test and masking stimuli, the more pronounced masking will be. Several authors have indeed found this to be the case in a number of different instances. Schiller (1966) used light-flashed letters of equal durations as both the test and masking stimuli. The degree of overlap between the test and the mask was varied, and a recognition task was employed. The author found that the amount of masking increased (that is, recognition scores declined) as the degree of overlap between the test and masking stimuli increased. This led him to conclude that his results implied that masking should be most pronounced in the case in which the test and the mask are identical. In a similar study in which black letters were masked by light-flashed stimuli which exhibited various degrees of patterning, Schiller and Wiener (1963) found masking to be at a maximum when intermediate amounts of patterning were used in the mask. On the basis of this finding, the authors suggested that two criteria regarding spatial parameters must be adhered to if the greatest amount of masking is to take place: a) there must be a high degree of similarity in the pattern contrast of the test and the mask; and b) there must be maximal physical overlap between these two stimuli.

An experiment by Sekuler (1965) mentioned earlier represents an interesting departure from most backward masking studies, yet it yielded results analogous to those already described. Sekuler used a black bar as a test stimulus and measured its duration threshold when it was masked by spatial frequency gratings composed of bars identical to the test stimulus. He varied the size of the angle (α), and therefore the amount of overlap between the test and masking stimuli and found that the duration thresholds for the detection of the test decreased with increasing α. This was true for both horizontal and vertical test and masking stimuli.

Kolers (1962) also measured the duration thresholds of test stimuli in a study that directly tested the role of contour or the amount of spatial overlap upon masking. He employed light-flashed discs as both test and masking stimuli. Although the diameter of the test flash was held constant at 30' of visual angle, the diameter of the mask was varied from 40'-200' of visual angle. He found that as the test and mask approached the same size, that the threshold measures for the test stimuli became higher. Stecher (1971) carried Koler's experiment to its logical end in that he used light-flashed discs of equal diameter (2^{o}) as test and masking stimuli. He found intensity thresholds for the test flashes, and concluded that equal-sized test and masking stimuli yielded more extensive masking than did similar studies employing tests and masks of unequal diameters. Unfortunately, he did not include any conditions in his own experiment in which the test and mask were not of the same size.

Sturr, Frumkes, and Veneruso (1965) utilized a rather unusual paradigm in which the mask was presented both before and after the test to explore the effects of changes in spatial parameters upon masking. Using black-on-white discs as stimuli, they measured the duration threshold of a test 10' in diameter preceded and followed by a mask which was varied from 15'-30' in diameter. They found a decreasing masking effect as the mask increased in size with respect to the test. Sturr and Frumkes (1968) used an identical paradigm to obtain the same results with a mask ranging in diameter from 15'-2° and a test stimulus 10' in diameter. In both studies the effects were the same with both foveal and peripheral presentation of stimuli.

Frumkes and Sturr (1968) performed an experiment better designed to separate the effects of backward and forward masking than were the two above-mentioned experiments. Measures of luminance thresholds for test flashes 43' in diameter were taken for various intervals between the test and conditioning (or masking) flashes. These intervals ranged from -200 to 200 msec, with the negative values representing a backward masking paradigm. The size and luminance of the conditioning flash was varied from 57' to 3°30' and from 15.9 to 0.5 mL, respectively. Presentations of stimuli were made both foveally and peripherally. The authors found that ". . . in general, the diameter for maximal increment threshold becomes progressively larger as luminance is decreased or as stimulation occurs farther in the periphery," but specifically that the foveal presentation of higher luminance masking stimuli of increasing diameter led to decreases in test threshold. Finally, the results of a similar study by Battersby and Wagman (1962), which included test and masking stimuli of the same size were in agreement with those of Frumkes and Sturr. Once again, these authors demonstrated that when the size of the masking (or conditioning) stimulus was varied, that it became more effective as its size approached that of the test, and that maximal masking occurred when the test and mask were equal in diameter.

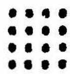
Two-Flash Discrimination Studies

Another type of experiment in vision--the two-flash discrimination study--is rather similar to the case in masking in which the test and masking stimuli are of equal size. These studies are usually concerned with finding the minimal gap (i.e., the gap detection threshold) at which two sequentially presented, spatially overlapping light flashes of the same size can be detected as being two separate flashes. At very short gaps or ISIs the two flashes are reported by subjects as being seen as one flash. Although this paradigm differs from most masking paradigms in that in two-flash discrimination studies the two stimuli are usually of the same duration, (in masking studies the masking stimulus is typically much longer than the test stimulus), some similarities between the results obtained from the two types of studies can be drawn. Several experimenters (e.g., Kietzman, 1967; Mahneke, 1958; Purcell & Stewart, 1971) have found that as the duration of the two stimulus flashes increases, the gap detection threshold (in terms of ISI) decreases. Another finding from the two-flash discrimination literature which will be pertinent to one part of the present study is that of Lewis (1968), who found that as the area of the two flashes increases, the gap detection threshold decreases.

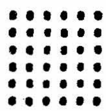
Rationale for the Present Study

Thus, the importance of the amount of spatial overlap between test and masking stimuli has been found to be a critical factor in backward masking in a number of experiments which have employed a wide variety of techniques. But the specific temporal determinants of test stimuli which approximate the spatial characteristics of the mask have not to this author's knowledge been studied. Perhaps the conflicting findings in experiments exploring the temporal parameters in masking exist because the relationship between spatial and temporal parameters has not been fully investigated. It is therefore the purpose of this proposal to obtain duration thresholds for three test stimuli of different sizes, (see Figure 2), which in two cases successively approach (the 4- and 16-point stimuli) and in one case equals (the 36-point stimulus) the size of a 36-point mask. Detection thresholds will also be found for the 4- and 16-point stimuli when they are masked by themselves. In this way the critical temporal determinants (whether ISI or SOA) can be determined for test stimuli which exhibit varying degrees of spatial and border overlap with a masking stimulus, and for the special cases in which the test and mask are equivalent.

4-point stimulus
(.25°)



16-point stimulus
(.50°)



36-point stimulus
(.86°)

Figure 2. The three stimuli used in the experiment and the degrees of visual angle subtended by each.

METHOD

Subjects

Two trained observers with normal visual acuity served as subjects. Both observers had considerable experience as subjects in psychophysical experiments.

Apparatus

Stimuli were presented on a VR-14 cathode ray tube driven by a PDP-8 digital computer. The surface of the cathode ray tube was coated with an ultra-short persistence phosphor (P24). The rapid light decay time of this phosphor (a few microseconds) allows for strict control of the time course of any stimulus displayed on the VR-14 cathode ray tube.

Individual dark-adapted subjects sat in a lightproof room facing the VR-14, with their heads supported in a chin rest. Subjects viewed the stimuli monocularly, from a distance of 60 cm.

The experimenter initiated each trial by means of a teletype interfaced to the computer and located in an adjacent room. Subjects communicated their responses to the experimenter via an intercom.

Materials

Three stimuli, composed of points of light, were used as either test or masking stimuli, or both, at different times during the course of the experiment. The stimuli were a 36-point square, subtending $.86^\circ$ of visual angle; a 16-point square, subtending $.50^\circ$ of visual angle; and a 4-point square, subtending $.25^\circ$ of visual angle. The three test stimuli were concentric with each other, and there was complete spatial overlap between the points of all three stimuli. The luminance level of all three test stimuli was held constant at .80 ft-L.

The viewing area within which the stimuli appeared was indicated by the presence of fixation crosshairs--that is, a set of 4 lines, one positioned off the midpoint of each of the 4 sides of the square formed by the 36-point stimulus and $.50^\circ$ of visual angle away from that side of the 36-point stimulus. Thus, the entire fixation area was a square subtending 1.86° of visual angle. Subjects were instructed to fixate on the area enclosed by these crosshairs throughout each trial.

Procedure

Three experiments were performed in which the test and masking stimuli and the range of test durations and ISIs differed. The general procedure for all of the experiments, followed by the stimulus and parameter specifications for each individual experiment, are given below.

Detection was measured in a forced-choice task. On any experimental trial, either a test and a mask or a mask alone (catch trial) were present. The subject's task was to report whether or not he detected the presence of the test stimulus. The temporal ordering of events on each trial was as follows:

The fixation crosshairs appeared for one second by themselves and remained on throughout the trial. After this 1 second interval, if the trial was to be a catch trial, a mask appeared for 500 msec, and the trial was completed. If the trial was <u>not</u> to be a catch trial, one of the test stimuli was presented prior to the mask at a fixed ISI for a variable duration. After the constant ISI the mask appeared for 500 msec, thus completing the trial.

Each subject participated in two training sessions, during which he was familiarized with the detection task. Within each training session the subject received two presentations of every possible test stimulus/test stimulus duration/ISI combination, plus an additional 10% catch trials. All such trials were displayed randomly during the training sessions.

During experimental sessions, for each ISI value the test stimuli were presented at all durations 40 times, according to the method of constant stimuli. A subject completed one ISI condition over a period of two sessions; thus, each session consisted of 20 presentations of the stimuli at each set of durations, plus an additional 10% catch trials. The order in which ISI conditions were presented was randomly determined for each subject, with the constraint that all ISI conditions were to be viewed once by each subject before the second presentation of any ISI condition could occur. In addition, at the beginning of each experimental session, one of the random orders of stimuli from the practice sessions (from 22-25 trials) was presented to the subject as a warm-up for the task. Responses were not recorded.

The specific details of each experiment are as follows:

Experiment 1. All three stimuli--the 4-, 16-, and 36-point--were masked by the 36-point stimulus. The test stimuli were presented at 8 durations, ranging from 3-33 msec for the 4- and 16-point stimuli and from 72-128 msec for the 36-point stimulus. These durations were selected upon the basis of pilot data. Duration thresholds were measured for the 4- and 16-point stimuli at ISIs of 0-20 msec, and for the 36-point stimulus at ISIs of 15 and 20 msec. (Extensive pilot data indicated that duration thresholds could not be obtained for the 36-point stimulus at ISIs of 0, 5, and 10 msec.)

Experiment 2. As in Exp. 1, the three stimuli were masked by the 36-point stimulus. Duration thresholds were obtained for all three test stimuli at ISIs of 30, 40, and 50 msec. The test stimuli were presented at 5 durations, ranging from 3-15 msec for the 4- and 16-point stimuli. The ranges of durations for the 36-point stimulus varied with the different ISI conditions--3-18 msec for 50 msec ISI, 24-56 msec for 40 msec ISI, and 40-72 msec for 30 msec ISI. The smaller values and ranges of durations in Exp. 2 reflect the results of Exp. 1 and pilot work.

Experiment 3. The 36-point stimulus was not used in this experiment. Instead, the 4-point stimulus was masked by itself, and the 16-point stimulus was masked by itself. Duration thresholds were measured for both stimuli at ISIs of 15, 30, and 50 msec, and the ranges of durations for each stimulus varied with the different ISI conditions. For the 4-point stimulus the ranges were 152-184 msec for 15 msec ISI, 64-96 msec for 30 msec ISI, and 18-50 msec for 50 msec ISI. The ranges for the 16-point stimulus were 112-144 msec for 15 msec ISI, 48-80 msec for 30 msec ISI, and 6-38 msec for 50 msec ISI. These values reflect the results of extensive pilot work.

RESULTS

The total number of detections for each subject at each test stimulus/ISI/stimulus duration combination were tabulated. All data were then corrected for guessing, using the following formula (Kling & Riggs, 1971):

$$P_c = \frac{P_h - P_{fa}}{1 - P_{fa}}$$

where P_h = the proportion of "hits" or detections of a test stimulus when one was actually present, and P_{fa} = the proportion of "false alarms" or detections of a test stimulus when none was actually present. Each of these data points were then converted to Z scores. A regression analysis on the data for each stimulus at each ISI condition was performed. Thus, a different fitted function showing detection as a function of test stimulus duration was determined for each ISI/test stimulus condition for each subject. A total of 54 such functions (24 for Exp. 1, 18 for Exp. 2, and 12 for Exp. 3) were obtained. A duration threshold, defined as the test stimulus duration at which 50% of the stimuli were detected, was obtained for each of the functions. These duration thresholds for all three experiments are plotted as a function of ISI for subject JKH in Figure 3 and for subject DCH in Figure 4.

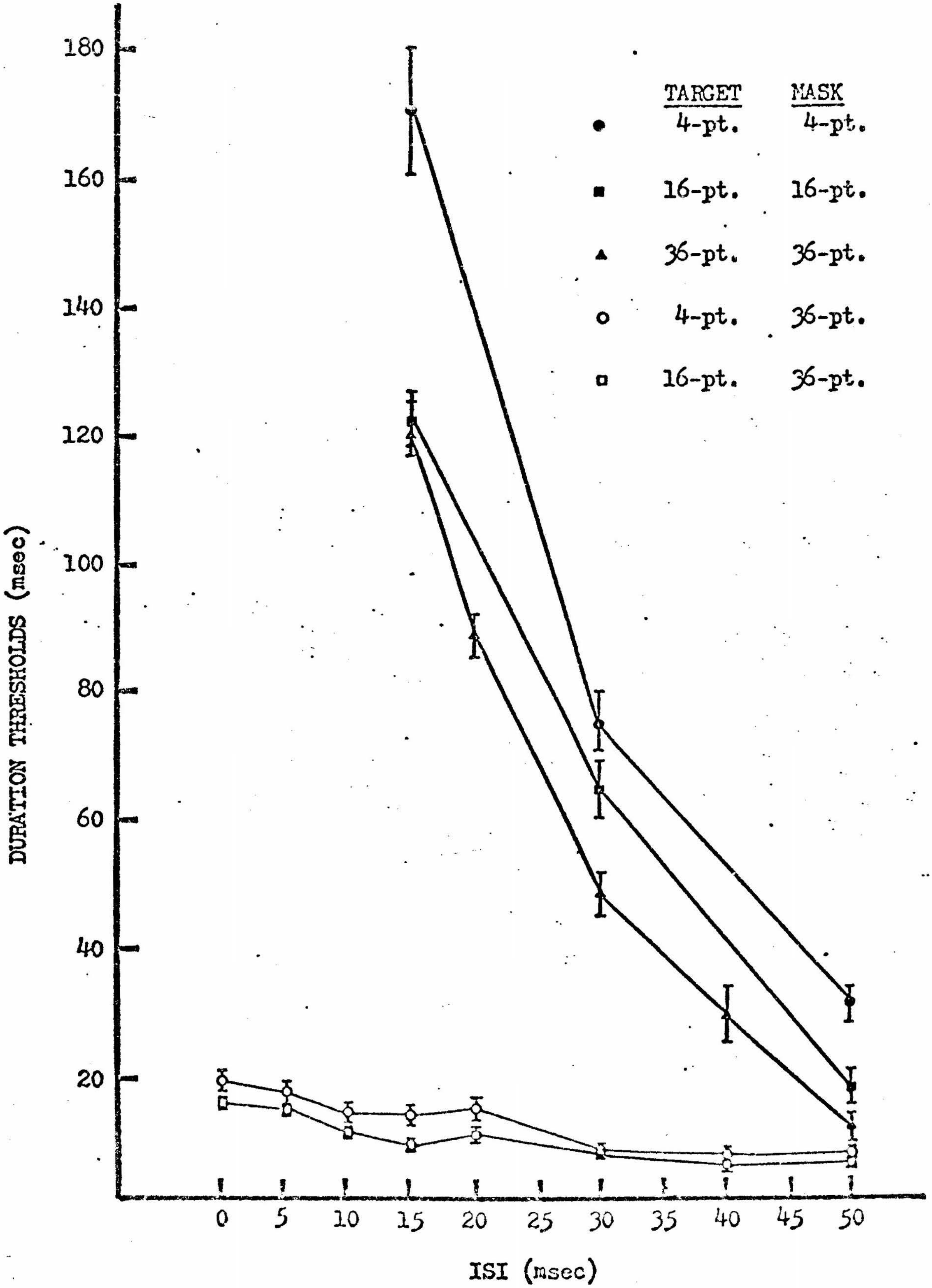


Figure 3. Duration thresholds for subject JKH.

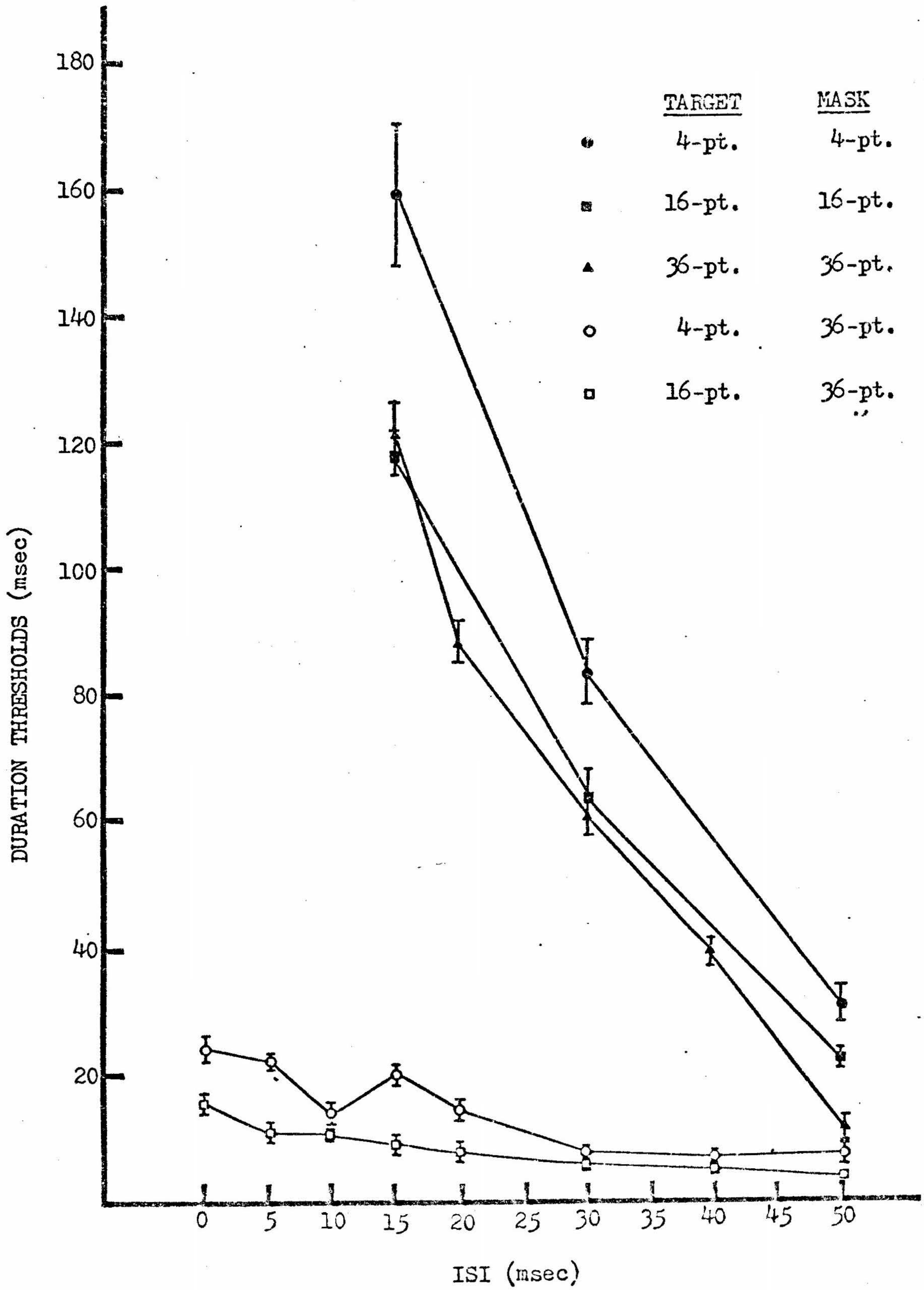


Figure 4. Duration Thresholds for subject DCH.

The brackets around each threshold point indicate the 95% confidence intervals for that threshold.

Several things should be noted about the functions in Figures 3 and 4. Visual inspection indicates that the forms of the functions are in good agreement across the two subjects. Also, the functions for which the test and masking stimuli are identical (indicated by the closed symbols) are similar in shape and are strikingly different from those for which the test and masking stimuli are non-identical (indicated by the open symbols). The former functions are elevated above and have much steeper slopes than the latter functions, all of which have rather shallow slopes. Thus, the duration thresholds decrease with increasing ISI for all of the functions, as expected, but this decrease is much more pronounced for the cases in which the test and masking stimuli are identical. In addition, among these functions, threshold duration increases with decreasing test-mask size. For the functions in which the 36-point stimulus is used as the mask, however, there is a non-monotonic relationship between the amount of masking and the size of the test stimulus, as shown by the lower duration thresholds of the 16-point test stimulus as compared to those of the 4-point test stimulus.

DISCUSSION

Two empirical formulations for temporal relations among the test and masking stimuli--ISI + test stimulus duration = a constant (Haber & Nathanson, 1969) and ISI X test stimulus duration = a constant (Kinsbourne & Warrington, 1962)--were set forth earlier in this paper to be tested as part of this experiment. The figures that resulted when the data from this experiment were substituted into the above two equations are shown in Tables 1 and 2. In general, the figures found in this manner increase with increasing ISI in the conditions in which the test and masking stimuli are non-identical and decrease with increasing ISI in the conditions in which the test and masking stimuli are identical. Unfortunately, a constant was not obtained for any test-mask combination while using either of the above formulations, although application of the formula ISI + test stimulus duration yielded smaller differences between each resulting figure. Because of the inconclusive nature of these data, it is not possible to determine from this experiment which temporal variable--ISI or SOA--is of critical importance in determining the extent of masking.

The effects of the spatial manipulations between the test and masking stimuli are quite marked. The significantly elevated thresholds and the steeper slopes of the functions for the conditions in which the test and masking stimuli were identical are seemingly difficult to explain in the light of previous studies. The non-monotonic relationship

Table 1. A test of the two temporal laws, using the data from subject JKH.

		ISI + Test Stimulus Duration		ISI X Test Stimulus Duration
			EXPERIMENT I	
			4-point Test Stimulus*	
	0	19.0		-----
	5	21.9		84.5
	10	23.8		138.0
	15	28.6		204.0
	20	34.4		288.0
			16-point Test Stimulus*	
	0	15.7		-----
	5	19.7		73.5
	10	20.9		109.0
	15	23.7		130.5
	20	30.5		210.0
			36-point Test Stimulus*+	
	15	135.9		1813.5
	20	108.2		1764.0
			EXPERIMENT II	
			4-point Test Stimulus*	
I	30	37.8		234.0
S	40	47.0		280.0
I	50	57.2		360.0
			16-point Test Stimulus*	
	30	37.1		213.0
	40	45.9		236.0
	50	56.0		300.0
			36-point Test Stimulus*+	
	30	77.4		1422.0
	40	68.4		1136.0
	50	61.2		560.0
			EXPERIMENT III	
			4-point Test Stimulus+	
	15	185.8		2562.0
	30	104.6		2238.0
	50	80.2		1510.0
			16-point Test Stimulus+	
	15	137.4		1836.0
	30	93.9		1917.0
	50	67.3		865.0

*Note: Indicates that the test stimulus was masked by the 36-point stimulus.

+Note: Indicates that the test stimulus was masked by itself.

Table 2. A test of the two temporal laws, using the data from subject DCH.

ISI	ISI + Test Stimulus Duration		ISI X Test Stimulus Duration
		EXPERIMENT I	
		4-point Test Stimulus*	
0	23.2		-----
5	26.4		107.0
10	27.2		172.0
15	35.2		303.0
20	37.3		346.0
		16-point Test Stimulus*	
0	18.9		-----
5	18.4		67.0
10	23.6		136.0
15	27.7		190.5
20	29.6		192.0
		36-point Test Stimulus*+	
15	134.0		1785.0
20	113.1		1862.0
		EXPERIMENT II	
		4-point Test Stimulus*	
30	39.6		288.0
40	47.8		312.0
50	57.4		370.0
		16-point Test Stimulus*	
30	37.1		213.0
40	44.7		188.0
50	52.5		125.0
		36-point Test Stimulus*+	
30	90.7		1821.0
40	80.5		1620.0
50	62.5		625.0
		EXPERIMENT III	
		4-point Test Stimulus+	
15	173.9		2383.5
30	112.9		2487.0
50	81.3		1565.0
		16-point Test Stimulus+	
15	130.5		1732.5
30	96.7		2001.0
50	74.9		1245.0

*Note: Indicates that the test stimulus was masked by the 36-point stimulus.

+Note: Indicates that the test stimulus was masked by itself.

between the amount of spatial overlap and the amount of masking does not agree with the results of Battersby and Wagman (1962) and Frumkes and Sturr (1968), who found that as the size of the masking stimulus approaches that of the test stimulus that masking is more pronounced. Although, in this experiment, the cases in which the size of the test stimulus equals that of the masking stimulus produce the strongest masking effects, in the cases in which the 36-point stimulus serves as the mask, the thresholds for the 4-point test stimulus are elevated above those for the 16-point test stimulus. This latter result does not agree with the findings mentioned earlier because the test stimulus furthest in size from the masking stimulus did not yield the lowest thresholds--that is, the 4-point stimulus is more difficult to detect than is the 16-point stimulus, when both are masked by the 36-point stimulus. It should be noted that both Battersby and Wagman and Frumkes and Sturr held the size of the test stimulus constant and manipulated the size of the masking stimulus. One could then argue that in the present experiment, in the conditions in which the 36-point stimulus was used as the mask, the 16-point test stimulus is more easily detected than is the 4-point test stimulus, because the 16-point stimulus contains more energy; that is, the 16-point stimulus is composed of 12 more points of light than is the 4-point stimulus. This areal summation effect does not extend to the case in which the 36-point stimulus is masked by itself, however. In this case the thresholds are strikingly elevated above those of the other two stimuli, even though the 36-point stimulus contains much more energy than either of them.

Lateral inhibition is one mechanism mentioned by M. L. Matthews in 1971 and Frumkes and Sturr in 1968 which may possibly explain the results obtained in this experiment. This physiological process produces an enhancement of the border of a dark-light field. In the present experiment when the 4- and 16-point stimuli are masked by the 36-point stimulus, the borders of the test and masking stimuli do not overlap. Since all of the points that the test and masking stimuli have in common overlap completely spatially, it may be that detection in this experiment consists of detecting the presence of the borders of the test stimuli. Therefore, the enhanced borders of the 4- and 16-point stimuli may facilitate the detection of those stimuli in the cases in which they are masked by the larger 36-point stimulus. But in the three cases in which the test and masking stimuli are identical, their light-dark borders coincide. Since the borders of both the test and masking stimuli are enhanced, the facilitating effects of lateral inhibition on detection of the test stimulus are lost under these conditions.

Another possible mechanism mediating detection, which has not to this author's knowledge been put forth by previous investigators, is apparent movement. Sperling (1965) noted that in the case in which the test and masking stimuli are non-identical that both spatial and temporal transients are present, while in the case in which test and masking stimuli are identical that only temporal transients are present. In this experiment, the presence of spatial and temporal transients gave rise to the phenomenon of apparent movement. Both subjects informally reported detecting the 4- and 16-point test stimuli, when they were masked by the 36-point stimulus, by attempting to discern movement as each trial was presented to them. In the cases in which the test and masking stimuli were equal, however, neither subject reported seeing any movement at all. In these cases, as Sperling noted, only temporal transients or discontinuities indicated the termination of the test stimulus and the beginning of the masking stimulus. The task, therefore, became one of detecting the gap between the test and masking stimuli, such as in a typical two-flash discrimination study. Indeed, these data were in agreement with those of Lewis (1968), who, using a two-flash discrimination paradigm, found that as the area of the two flashes decreases, that the gap detection threshold increases. It is possible, then, that the presence of spatial and temporal transients between the test and masking stimuli leads to the appearance of movement, in that the test stimulus seems to expand toward the larger masking stimulus. In the absence of spatial transients, however, the subject must rely solely upon detecting the temporal gap between the test and masking stimuli.

At this point it is not possible to determine whether the best explanation of these data rests upon the phenomenon of lateral inhibition or the presence or absence of spatio-temporal transients, which lead to apparent movement. It may be that both of these mechanisms, operating independently, mediate the detection process.

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The thesis is therefore accepted in partial fulfillment of the requirements for the degree of Master of Arts.

5-5-77
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